An integrated study of the Gladstone Marine System

Gladstone Harbour biogeochemical and seagrass growth model

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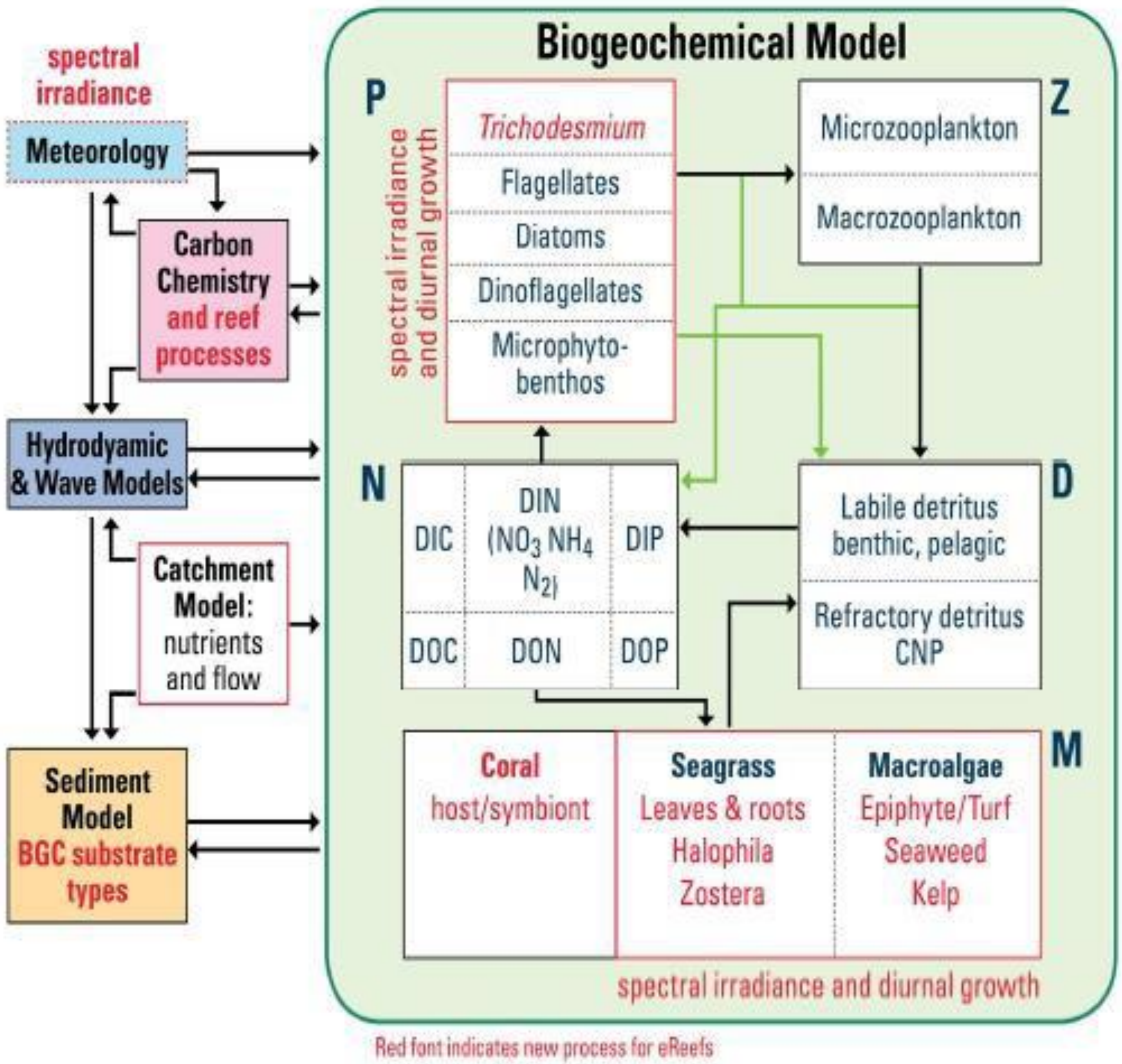
11–12 August 2015

Biogeochemical modelling and seagrass.

Project began with a recognition that:

- Seagrass dynamics can only be understood if environmental conditions are well represented ➔ need for a coupled hydrodynamic biogeochemical model.
- Representing light-limitation is critical, and that it is desirable to consider light at multiple wavelengths ➔ spectrally-resolved optical model.
- Existing seagrass models miss processes that observational studies suggest are critical ➔ translocation of biomass between leaves and roots, uptake of nutrients from varying depths in the sediments, physiological differences between seagrass types.
- Model improvements in GISERA would be valuable for future applied studies in Gladstone (GHHP) and along the whole Queensland coast (eReefs).

CSIRO Environmental Modelling Suite (EMS)



N – nutrients

P – phytoplankton

Z – Zooplankton

D – Detritus

M – Macrophytes.

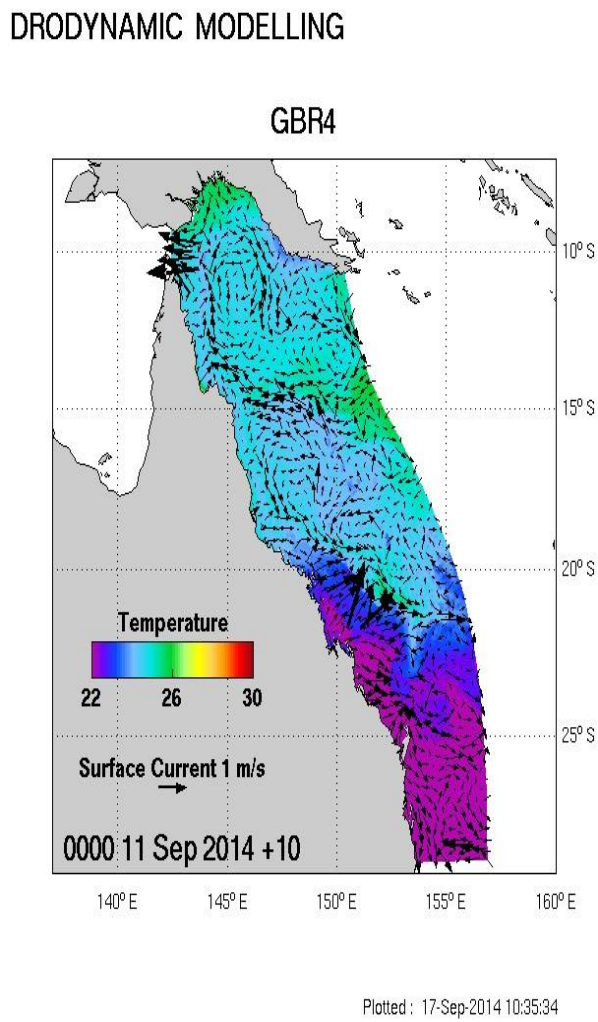
In biogeochemical model:

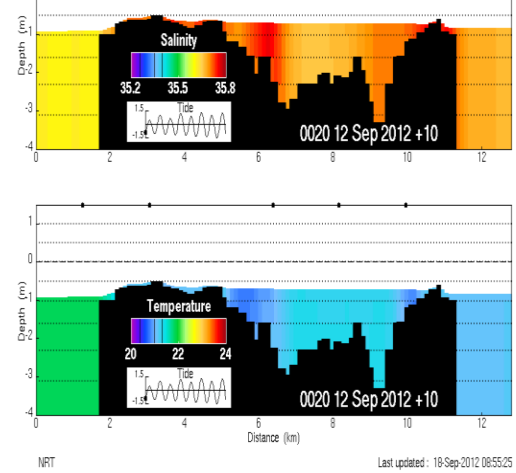
Boxes – stores of nutrients

Arrows – fluxes of nutrients.

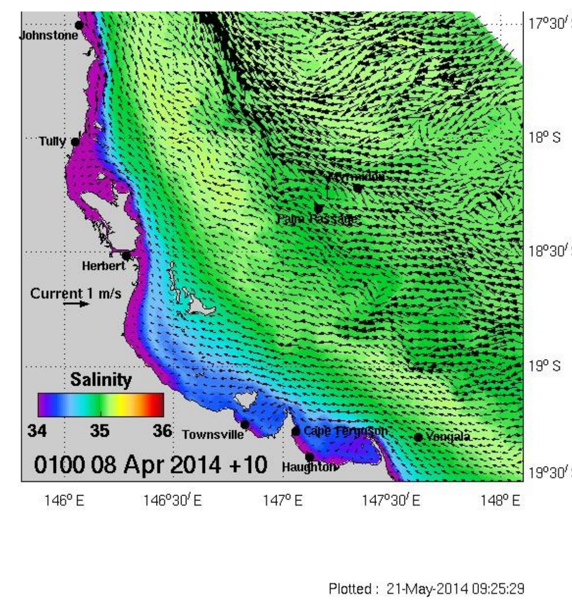
Regional hydrodynamic models

- Hydrodynamic models of 4 km and 1 km forced by global model and 22 rivers.
- Hindcast from Sep 2010 – present day.
- Near real time.
- 4 km version resolves interaction of large rivers, reef matrix, shelf and open ocean.
- 1 km resolves individual reefs, river plumes etc.
- 200 m resolution models forced by GBR4 and GBR1 resolves reef crest / reef lagoon / river entrances.





200 m regional models



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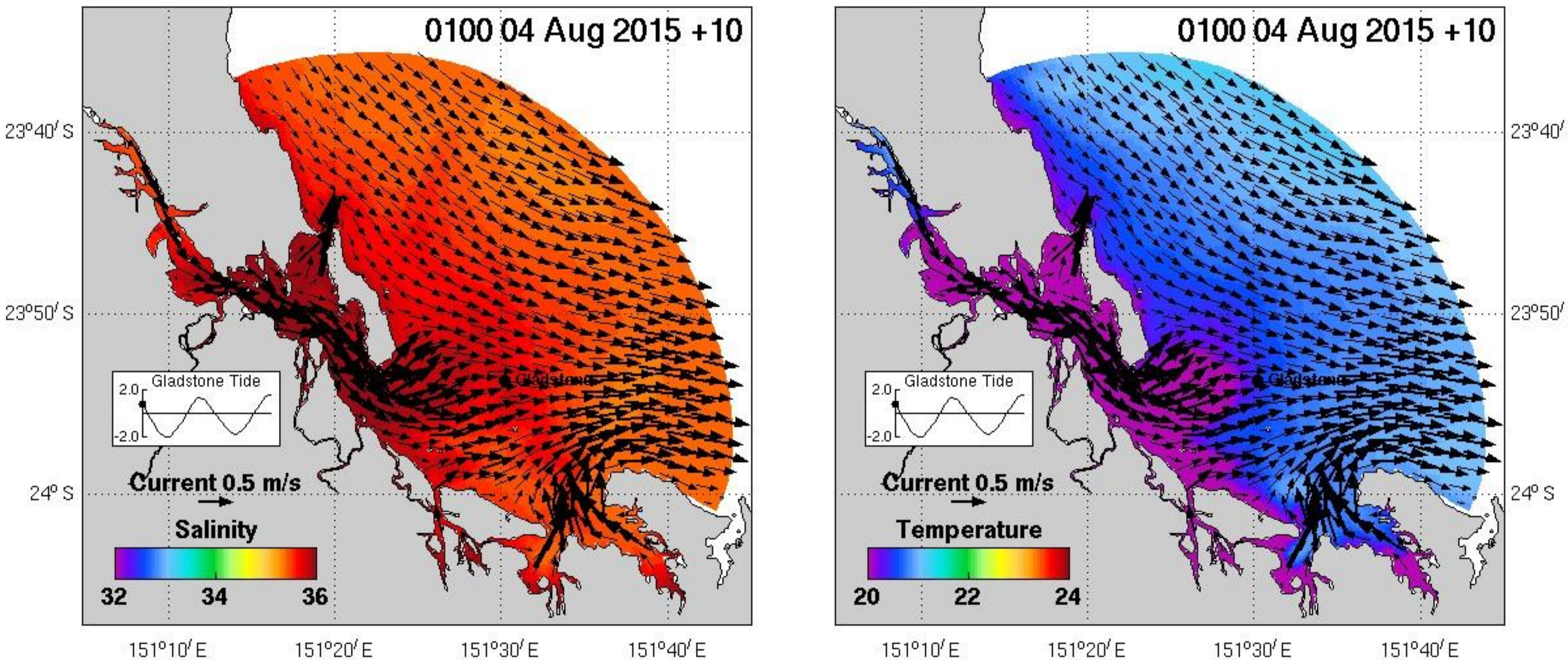
PORT CURTIS

NEAR REAL-TIME HYDRODYNAMIC MODELLING

Surface Salinity

NRT

Surface Temperature



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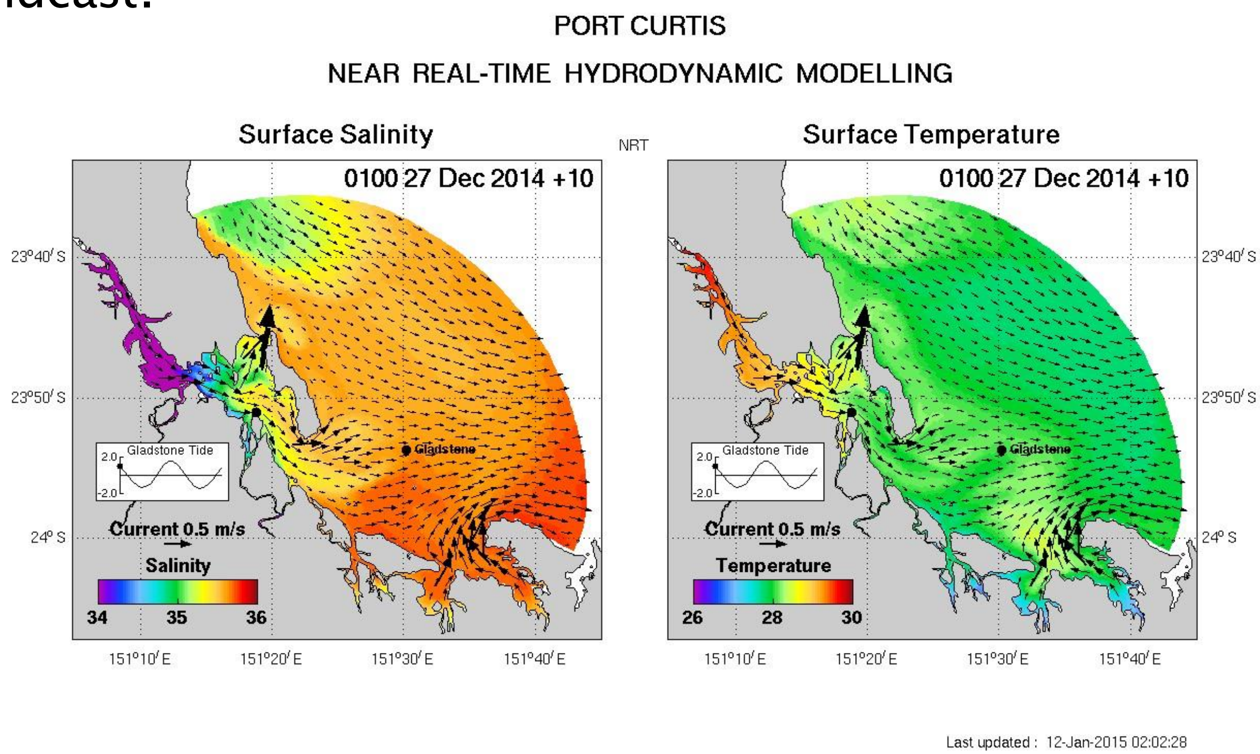
GHHP Harbour Receiving Water Quality Model

- Approx 200 m resolution model hydrodynamic model run for Sep 2010 to present.
- Calliope and Boyne Rivers resolved past the tidal limit.
- Atmospheric forcing from BoM, Calliope and Boyne rivers from QLD govt.
- Assessed against PCIMP sediment and biogeochemical and JCU seagrass observations, but produced without a dedicated observational program.
- Biogeochemical and sediment model ocean boundary conditions provided by eReefs 4 km 2010 hindcast.



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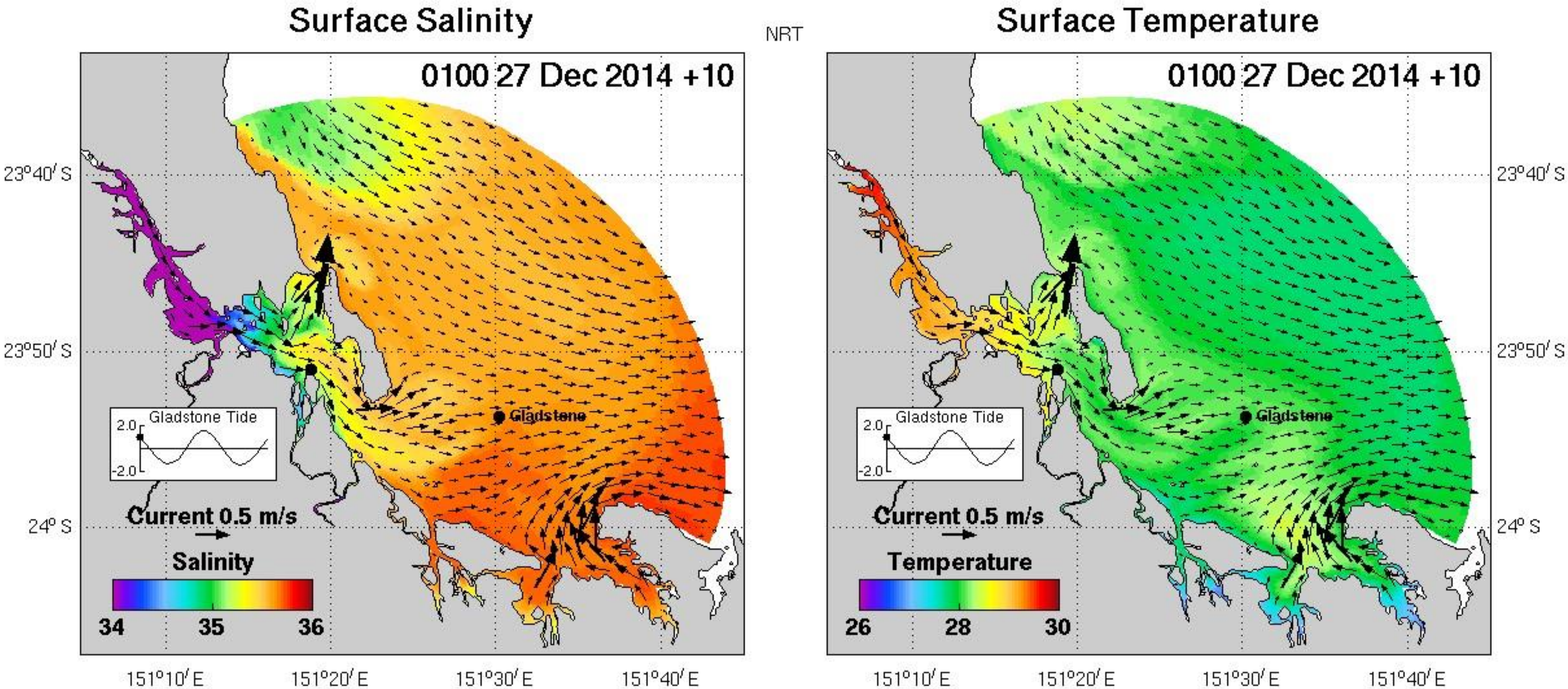

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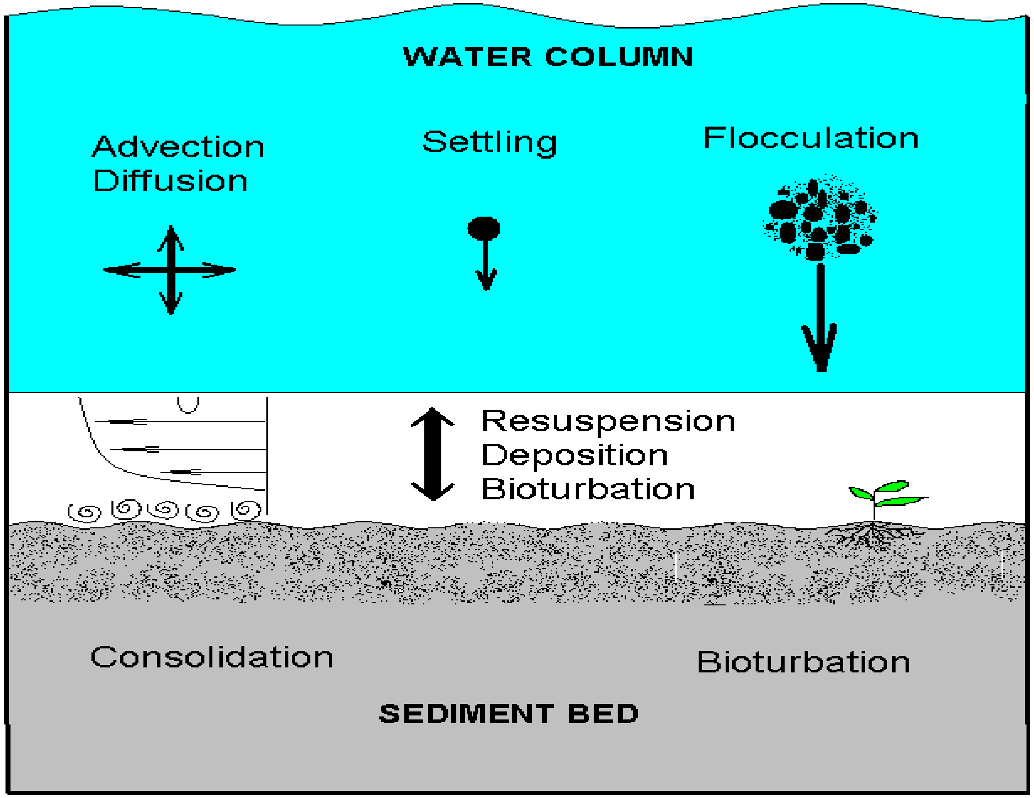
Sediment transport model

- Simulates sinking, deposition and resuspension of suspended sediment
- Adds a multilayer sediment bed to the EMS grid
- Is driven by 3-D hydrodynamics and wave data
- Provides physical settings to simulate biogeochemical model



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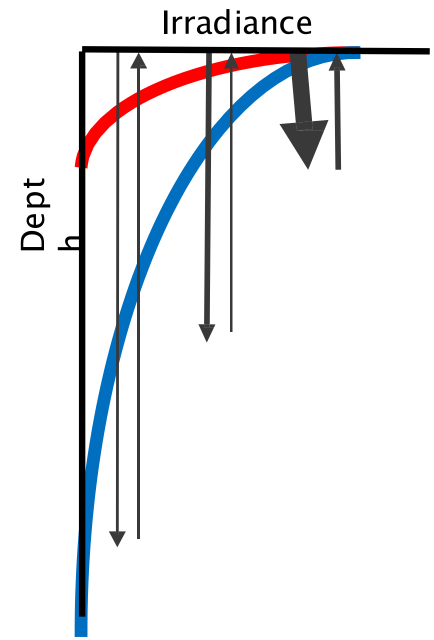
Optical model

Spectrally-resolved vertical attenuation of light due to scattering and absorption of (19 optically-active components in total):

- 4 phytoplankton classes with two pigments
- Coloured dissolved organic matter
- Suspended inorganic particles and detritus
- water molecules
- Bottom substrates - seagrass, macroalgae, benthic microalgae, corals (skeletons and symbionts).



Remote-sensing reflectance seen at surface (i.e. viewed by a satellite) comes from reflectance all depths ~ weighted by optical depth

Only about 3 % of light returns

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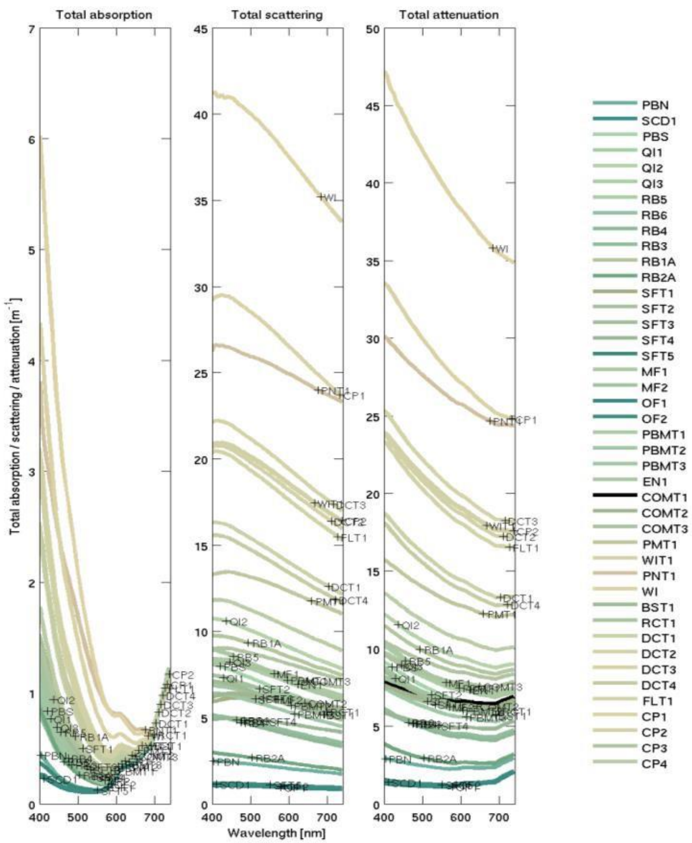
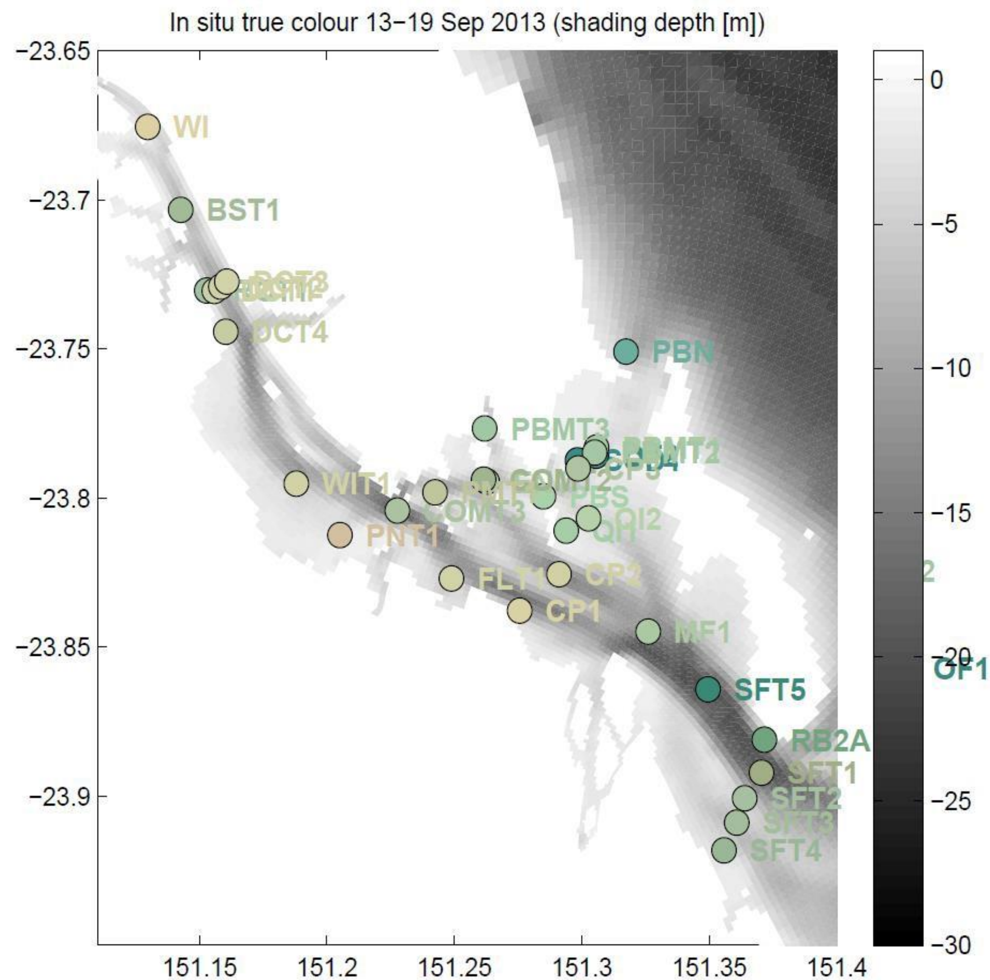
Optical model – Inherent Optical Properties (IOPs) from model state.

Suspended sediment properties – scattering / attenuation observations from an acs.





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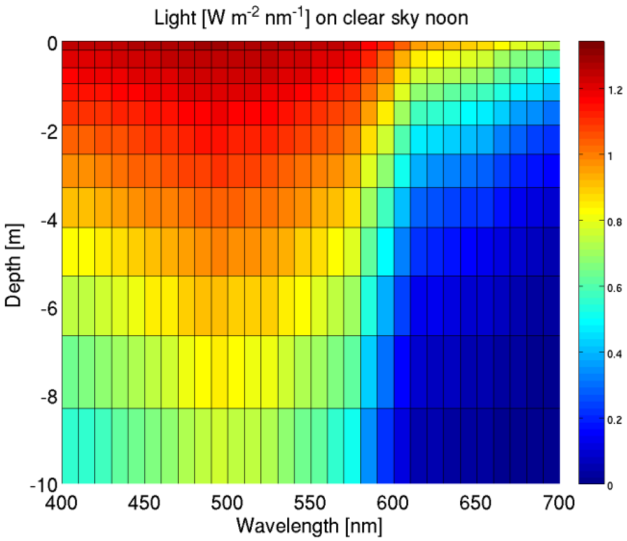
Results from optical model

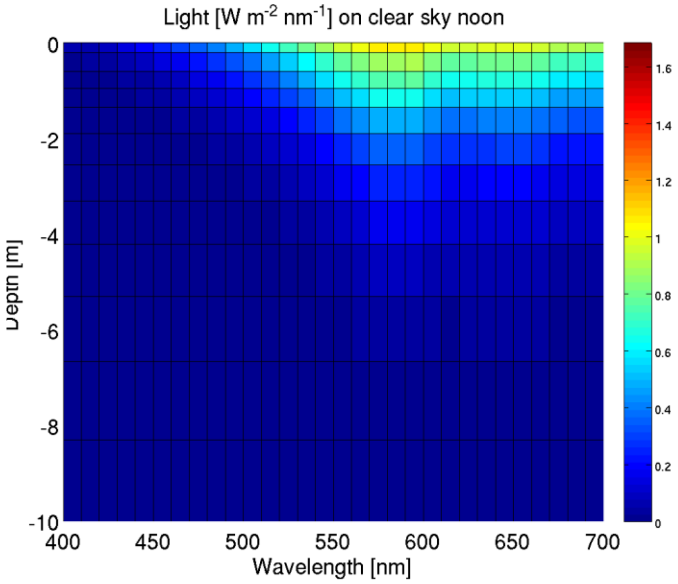
Optical model produces spectrally-resolved depth profile:

- Distinguish between impact of
    - sediment plume (scattering)
    - Phtyoplankton bloom (absorption at chl. pigment maximum

Offshore



Narrows



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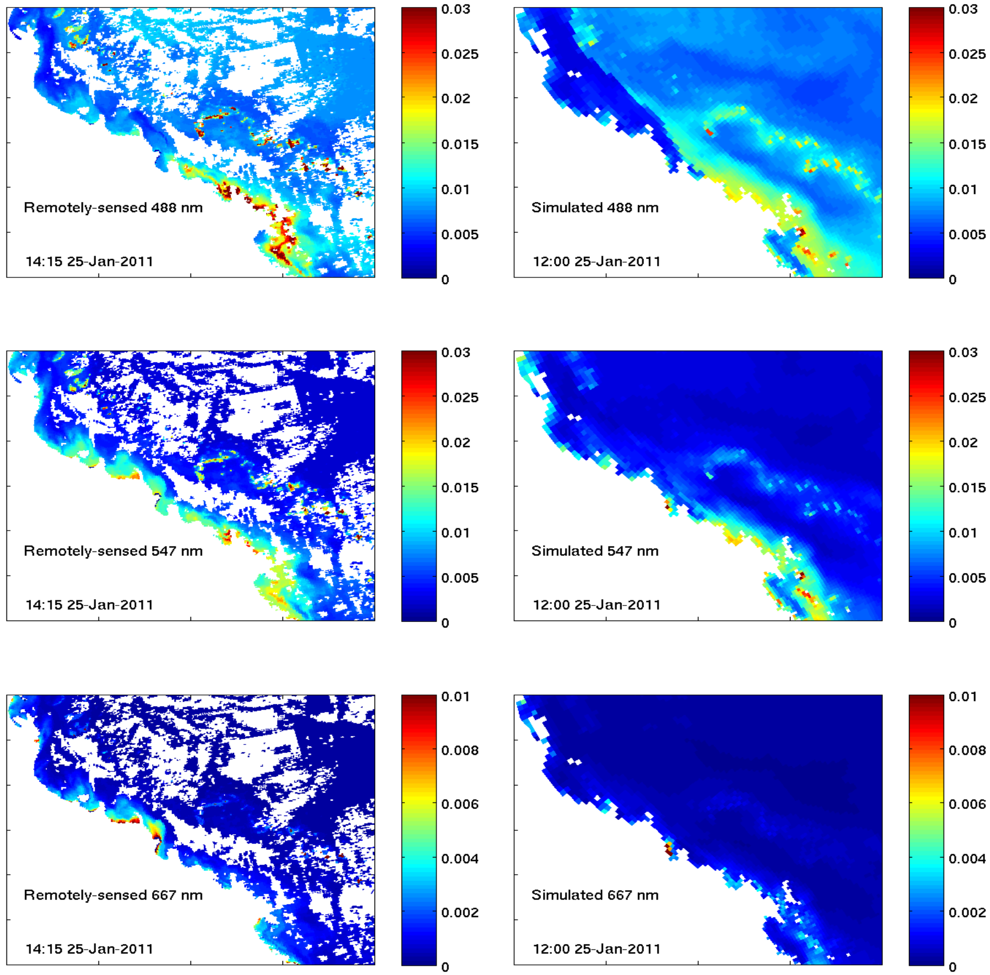
Observation of top of atmosphere (TOA) reflectance corrected for atmospheric scattering and absorption to obtain, cloud permitting, reflectance as viewed at a solid angle, R_{rs} [sr^{-1}]

Atmospherically-corrected | Simulated



Optical-depth weighted reflectance as a result of 20 optically-active constituents initialised 100 days earlier, and transported, biogeochemically-transformed, flocculated and resuspended, to determine reflectance at any time, viewed at a solid angle, R_{rs} [sr^{-1}]

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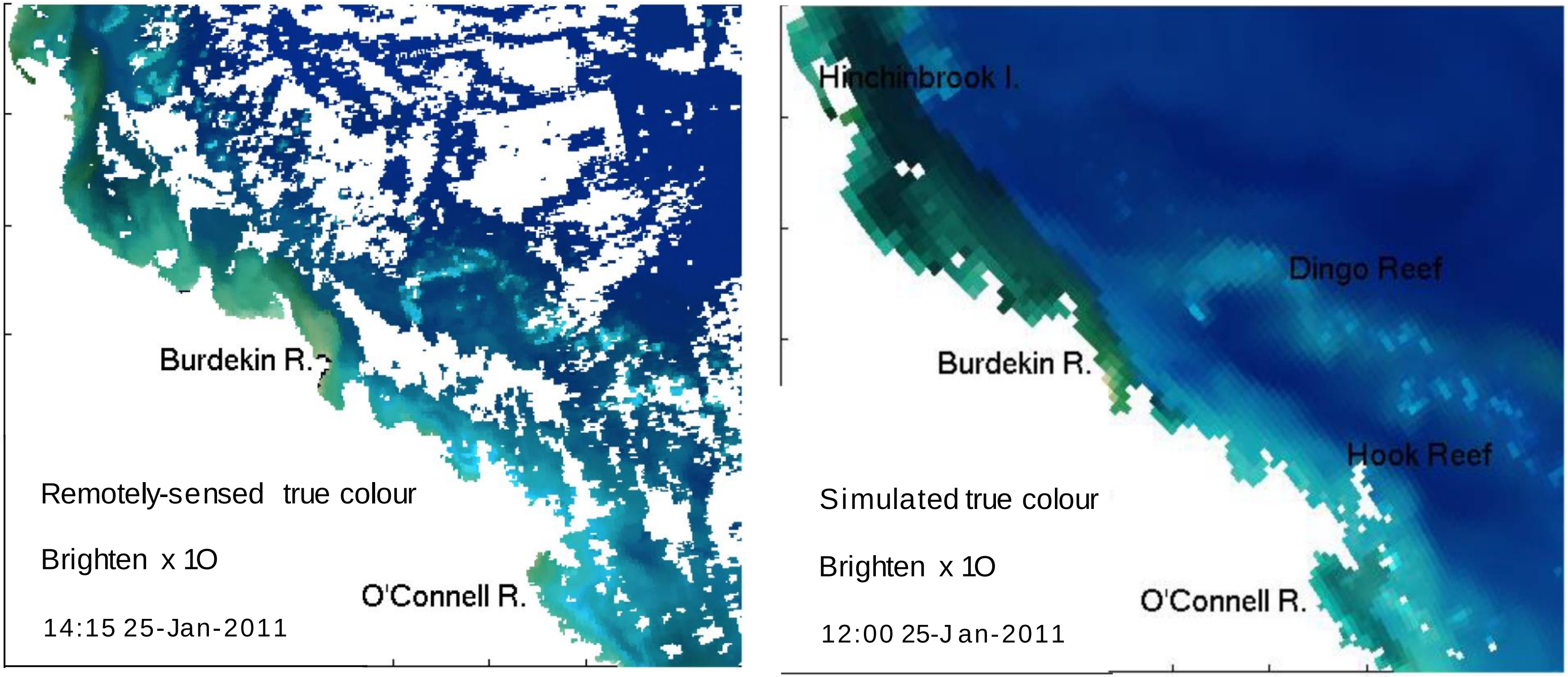
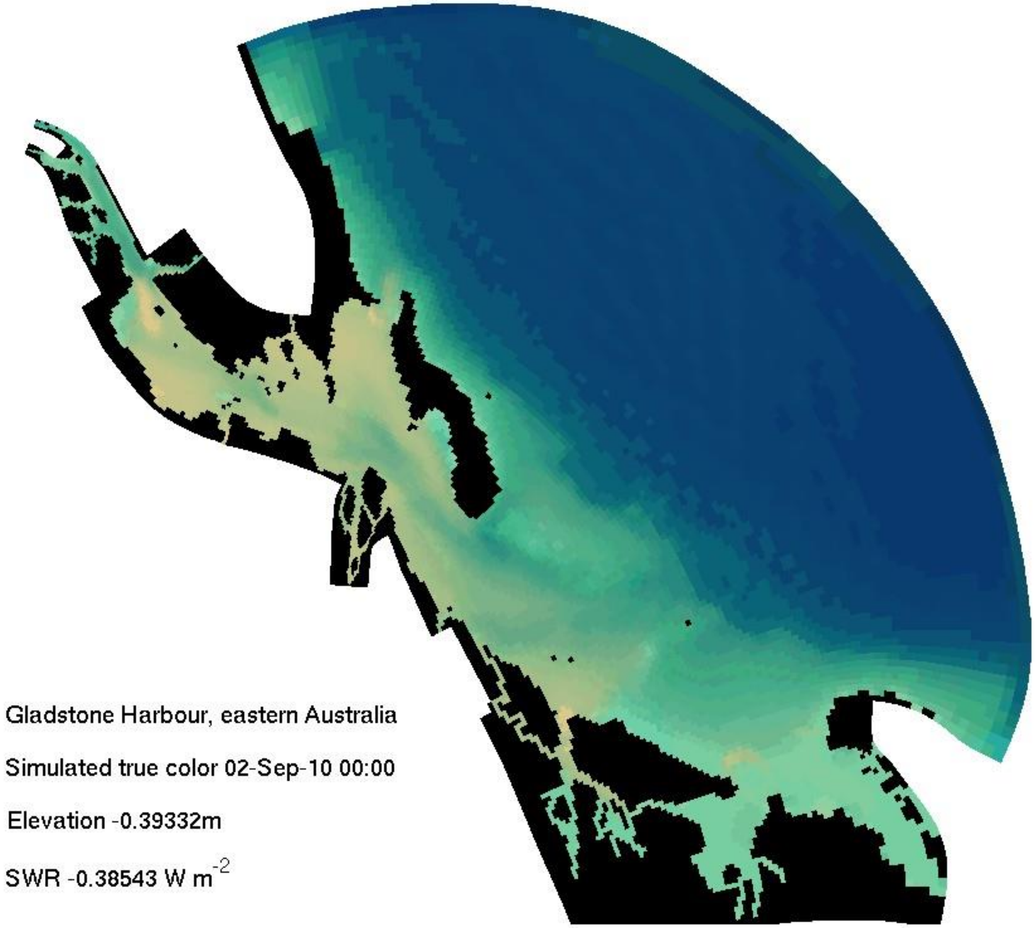

Burdekin R.
Remotely-sensed true colour
Brighten x 10
O'Connell R.
14:15 25-Jan-2011
Hinchinbrook I.
Dingo Reef
Burdekin R.
Hook Reef
Simulated true colour
Brighten x 10
O'Connell R.
12:00 25-Jan-2011

Simulated true colour animation in September 2010



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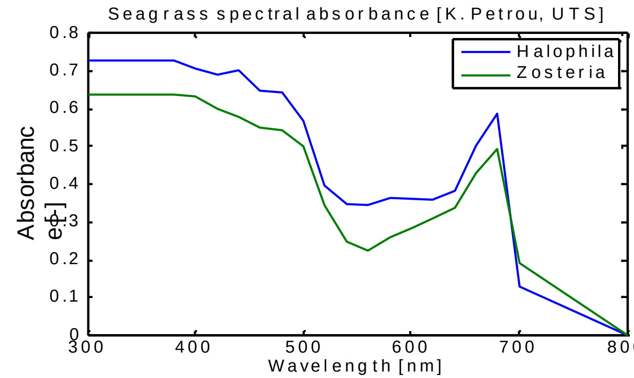
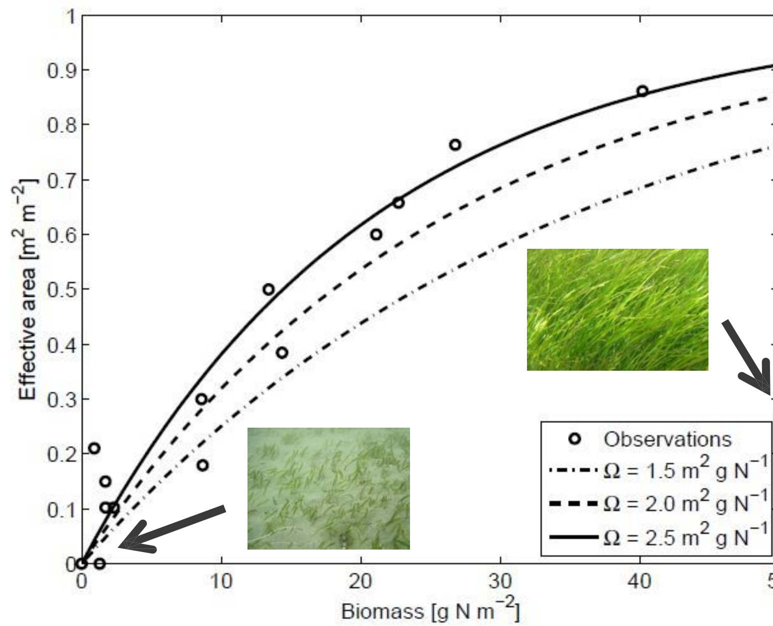
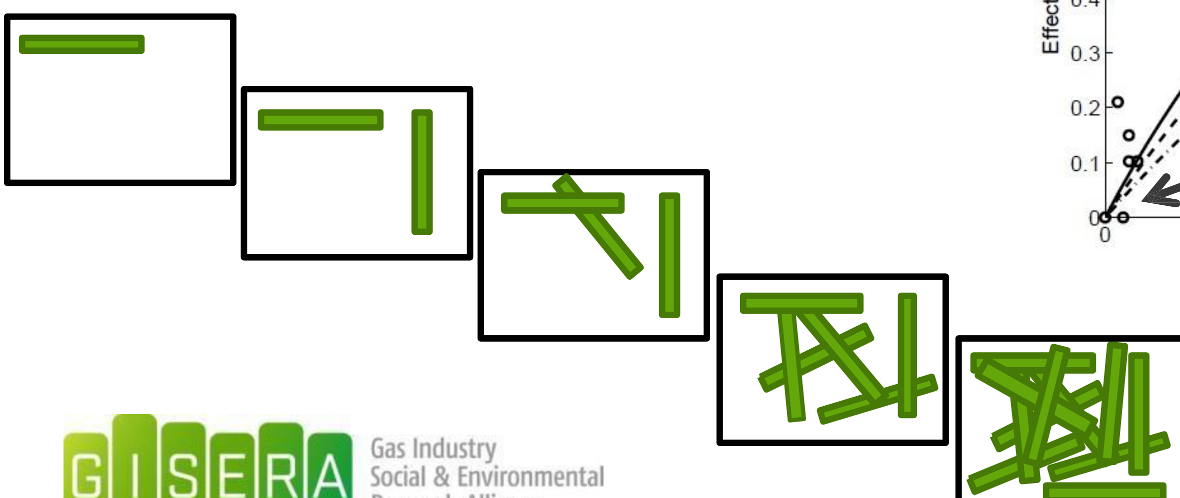
Seagrass model.

- Two seagrass types: Zostera and Halophila.
- Resolve above and below ground biomass.
- Spectrally-resolved absorption
- At low biomass, absorption is a linear function of biomass
- At high biomass independent of biomass.
- Curve follows a cumulative Poisson dist of probability of leaves covering each other as shown by the '+'.







$$\%\ \text{cover} = 1 - \exp(-\Omega B)$$

Thanks to Matthew Adams, UQ

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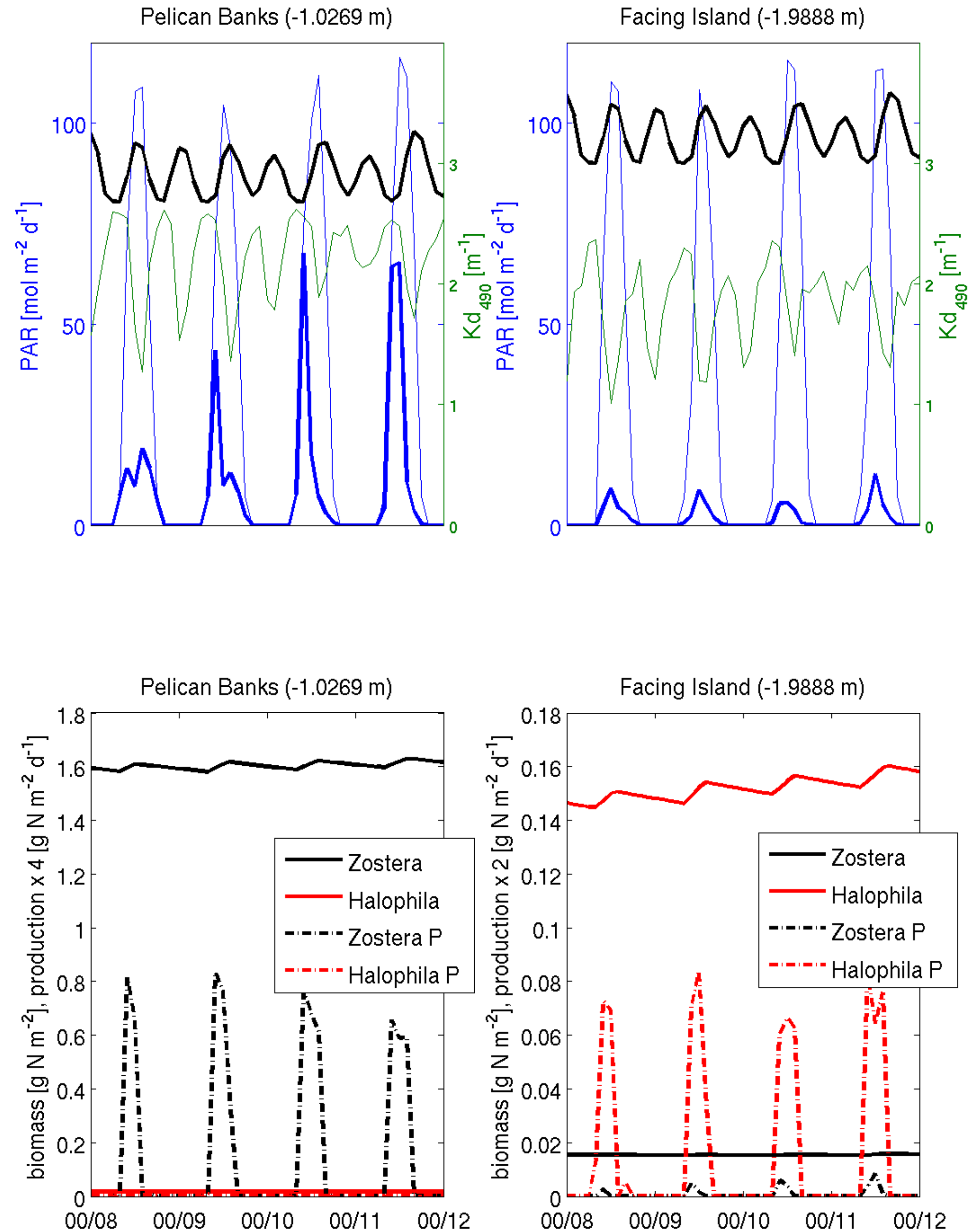
Results

What determines the light available to seagrass communities?

- Solar radiation (clouds etc.)
- Depth of water (varies with site, and point in tide)
- Vertical attenuation coefficient (K_d) that varies with suspended solids, chlorophyll concentration.

- Seagrass growth depends on the recent light history (see production).



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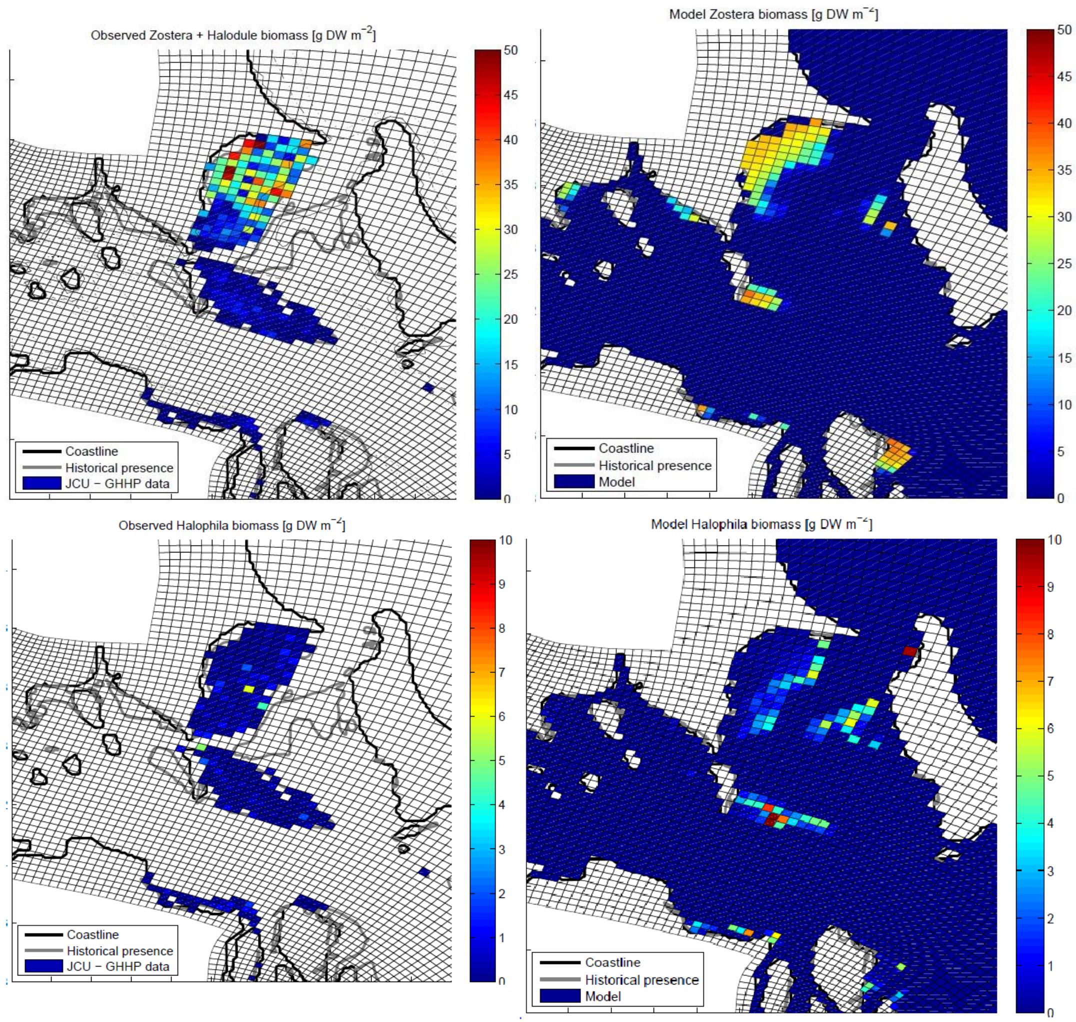
Comparison of GHHP configuration multi-species seagrass distribution after 2 year simulation with observed mean distribution over 2002-2012.

Model is spatially more homogenous, but generally produces realistic biomass and distribution of shallow and deeper water seagrass.

Thank you to the JCU TropWATER for providing the raw observations.



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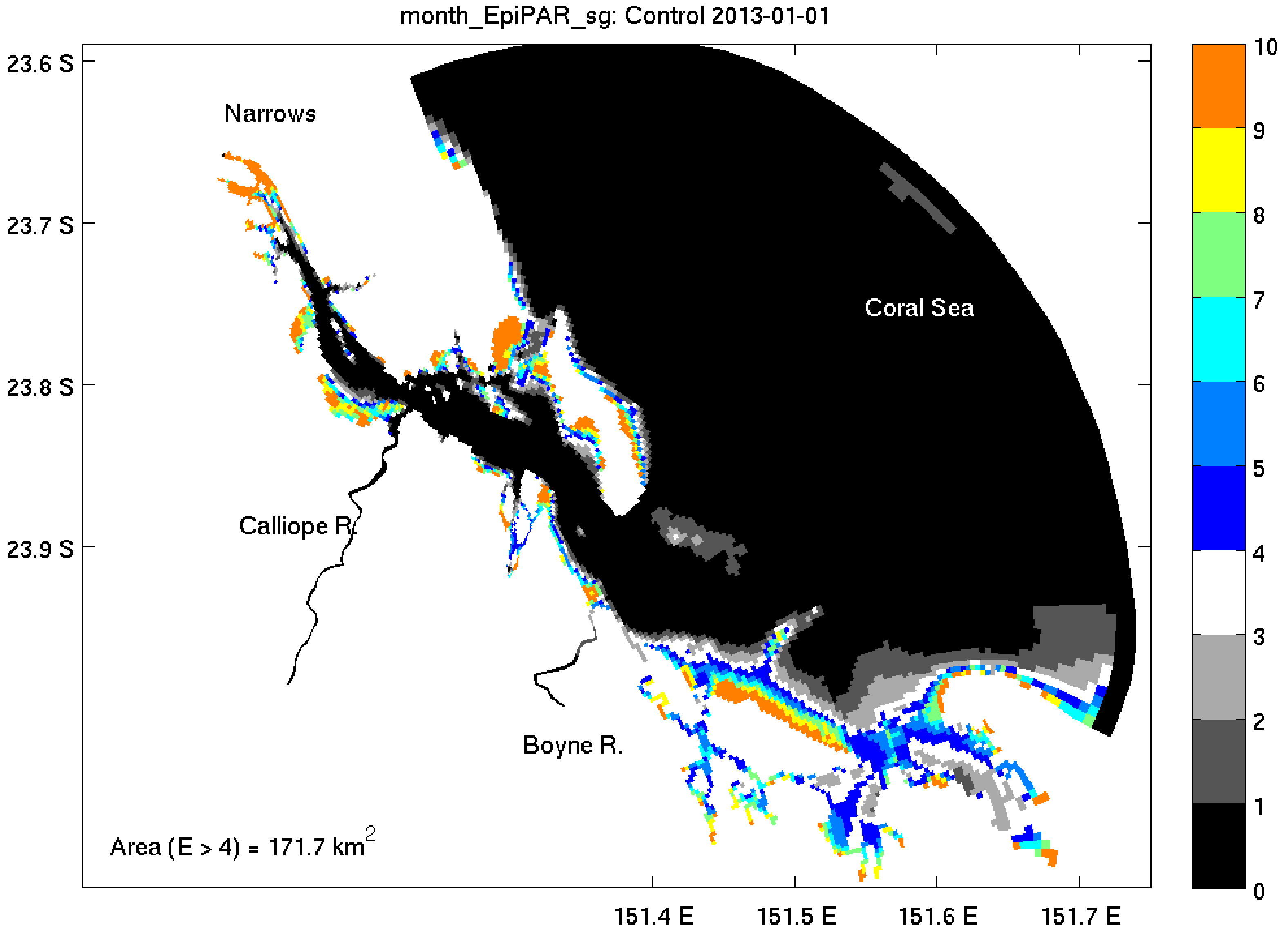
Running average monthly light above seagrass.



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Thank you

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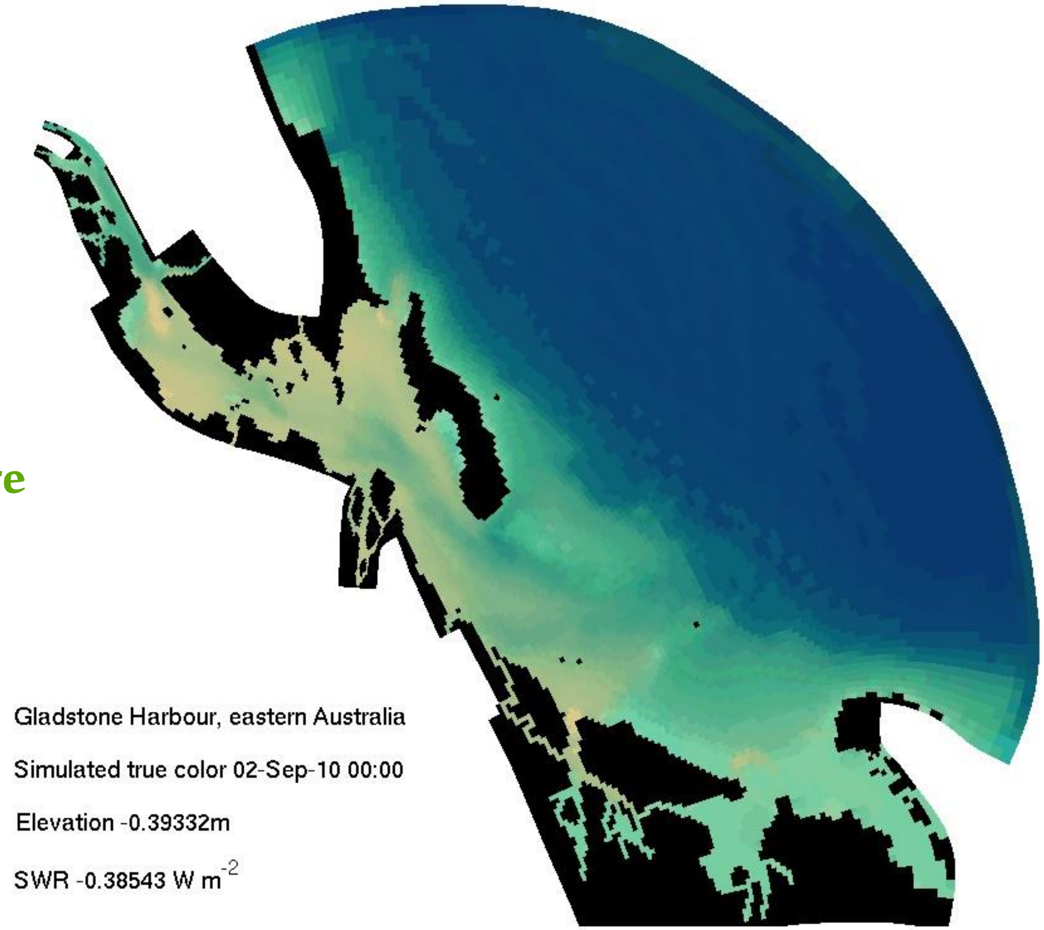

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